INNOVATIVE
TECHNOLOGY
SUMMARY REPORT
for the
Large Scale Demonstration and Deployment Project of Hot Cells

REMOTE DEMONSTRATION OF THE ELECTRODECON SYSTEM

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Demonstrated at
Idaho National Engineering and Environmental Laboratory
Idaho Falls, Idaho

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Purpose of this Document

Innovative Technology Summary Reports (ITSRs) are designed to provide potential users with the information needed to quickly determine whether a technology would apply to a particular environmental management problem. These reports are also designed for readers who may recommend that prospective users consider a technology.

Each ITSR describes a technology, system, or process that has been developed and tested with the funding from the Department of Energy (DOE) Office of Science and Technology (OST). The report presents the full range of problems that a technology, system or process will address and its advantages to DOE in terms of system performance, cost, and cleanup effectiveness. Most reports include comparisons to baseline technologies as well as other competing technologies. Information about commercial availability and technology readiness for implementation is also included. ITSRs are intended to provide summary information. References for more detailed information are provided in an appendix.

Efforts have been made to provide key data describing the performance, cost, and regulatory acceptance of the technology. If this information was not available at the time of publication, the omission is noted.

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SECTION 1
SUMMARY

Technology Summary

Accomplishing the decontamination of radioactive hot cells like those currently undergoing cleanup at the West Valley Demonstration Project (WVDP) and other sites within the DOE complex requires the removal and packaging of contaminated equipment as well as the removal of contamination from surfaces inside hot cells, including walls, ceilings and equipment surfaces. Standard methods for removing surface contamination, such as vacuuming or using strippable coatings, are effective for removing particulate matter, but cannot remove contamination that is chemically bonded (or fixed) to a surface. More aggressive methods for removing surface contamination, such as Ultra High Pressure (UHP) water jetting, vacuum steam cleaning or using a chemical decontamination agent, generate large volumes of liquid waste that must be treated and disposed. Using aggressive methods to clean metal surfaces can also result in the production of mixed waste, which puts severe limits on how the waste can be treated and disposed.

The electrochemical removal process known as electropolishing is an electrochemical treatment process first patented in 1912 that has since become the standard industrial method for mechanically polishing a wide range of metal parts, including gears, roller bearings, surgical instruments, pump and valve shafts, knives, fabricated tanks, and welded tubular products. As a controlled process capable of removing microscopic amounts of metal from an object’s surface in a manner that leaves the surface in a clean, microscopically smooth condition, electropolishing has recently been adapted for use as a technique to decontaminate radioactively contaminated metal objects that can be contact-handled.

The electrochemical decontamination process developed by ADA Technologies known as the ADA ElectroDecon (ED) system, combines electropolishing with the more standard technique of using strippable coatings to decontaminate metal surfaces without generating liquid waste or mixed waste streams that require further treatment. This system, which has been evaluated and considered for use at the Idaho National Engineering and Environmental Laboratory (INEEL) as a means for accomplishing various decontamination tasks, has the potential to be used for remote applications in hot cells like those located at the WVDP.

Demonstration Summary

The demonstration of the ED system discussed in this report was conducted at the Remote Mockup Test Facility (RMTF), which is located in the Test Reactor Area (TRA) at the INEEL. Testing was performed using all components of the basic ED system – a scrubbing shoe, ADA's proprietary electrolyte gel, a power supply, electrolyte pump module, electrolyte and current supply tether, anode terminal, abrasive scrub pads (Scotchbrite® pads), and an electrolyte gel pack. To perform test demonstrations, basic handling components of the system, like the scrubbing shoe, were modified for use with remote tooling identical to that used at the WVDP, a PaR 3000 vertically deployed power manipulator and a CRL Model F master-slave manipulator (MSM).

System performance was tested using two methods to determine system efficacy. The first method involved using a felt-tipped permanent ink marker (a Sharpie® Pen) to stain metal surfaces that were then cleaned using the ED system. The second method involved using simulated contamination (SIMCON) coupons to evaluate surface removal capabilities using the ED system. For the first method, removal efficiency was graded according to the percentage of stain visibly removed from the surface of the metal plate used for testing, with 90% removal equaling a high decontamination factor (DF), 70% removal equaling a medium DF, and less than 70% equaling a low DF. Other performance areas evaluated during demonstration testing included ease of use; expected worker involvement; volume and type of secondary waste generated; rate of application and removal; projected operating costs; radiation tolerance of the gel coating; and estimated deployment time, including equipment set-up and disassembly.

Overall test results showed that the ED system is a functional decontamination method suitable for remote application using MSM or PaR-type manipulators. Although several phases of the tests conducted yielded inconclusive results, the system as deployed in the RMTF showed that decontaminating surfaces using the ED system is a viable, low-cost way of decontaminating surfaces that is simple to configure, easy to use, and capable of generating low volumes of solid (dry) waste that are easy to manage.

Contacts

Technical

Rick L. Demmer, Bechtel BWXT, INEEL, Idaho Falls, ID, 83415
Phone: (208) 526-3412 email: **RICKD@inel.gov**

Richard L. Lane, Bechtel BWXT, INEEL, Idaho Falls, ID, 83415
Phone: email:

Timothy Milner, BNFL, Inc., West Valley Project Office, 10282 Rock Springs Road, West Valley, NY, 14171
Phone: (716) 942-4152 email: **tmilner@bnflinc.com**

Management

Jack Craig, Project Manager, USDOE- NETL, 626 Cochrans Mill Road, Pittsburgh, PA 15236-0940
Phone: (412) 386-4775; email: **craig@netl.doe.gov**

John Drake, USDOE, OH/WVDP, 10282 Rock Springs Road, West Valley, NY 14171
Phone: (716) 942-2114; email: **john.l.drake@wv.doe.gov**

James Gramling, LSDDP Project Manager, West Valley Nuclear Services Company, 10282 Rock Springs Road, West Valley, NY 14171
Phone: (716) 942-2119; email: **gramlij@wvnsco.com**

Licensing
No licensing involved

Permitting
No permits involved.

SECTION 2
TECHNOLOGY DESCRIPTION

Overall Process Definition

Standard processes used to accomplish surface decontamination are effective in the removal of loose contamination, but are far less effective in removing contamination that is chemically bonded (or fixed) to metal surfaces. Aggressive techniques can be used to remove fixed contamination from metal surfaces. However, they are also expensive to install, labor intensive, and produce large volumes of liquid (and frequently) mixed waste that requires further treatment and disposal. For example, various kinds of electrochemical decontamination methods produce aqueous wastes that require treatment for Resource Conservation Recovery Act (RCRA) metals.

The electrochemical decontamination process developed by ADA Technologies known as the ElectroDecon, or ED, system, employs a principle similar to that used in electropolishing. In electropolishing (actually a reverse plating technique), the surface of a metal object is cleaned or polished by immersing an object into a chemical solution through which a low voltage current is passed. In electrochemical decontamination using the ADA process, a special proprietary gel serves as the electrolyte (solution) through which a low voltage current is passed. When current is applied to the gel, positively charged ions (radioactive cations) on the surface of a contaminated metal object move away from the surface and into gel. Once this electrochemical reaction has occurred and the gel is left to dry or “cure”, it can then be removed from the surface like “strippable” coating suitable for packaging and disposal as a non-hazardous solid waste.

Previous testing of the ED system at the INEEL has shown it to be an effective means of removing simulated contamination from metal surfaces. The ED system has also been used at the INEEL to clean radiologically contaminated steel plate. This success has prompted the design and fabrication of several pieces of ED system equipment so that it can be deployed using robotic tooling similar to that used at facilities like the WVDP in West Valley, New York.

System Operation

Electrochemical decontamination using the ED system is accomplished by using a simple hand-held device called scrubbing shoe to apply a “sandwich” coating of electrolyte gel to the surface of the object to be cleaned. When electrical current is passed through the gel, contaminants and other materials on the object’s surface are drawn away from the surface toward a negatively charge anode behind the gel. As the contaminates (ions) move away from the object toward the anode, they become encapsulated in the gel. After allowing sufficient time for the gel to dry, or “cure” (about two hours for layer of gel from 15 to 25 mil (0.4 to 0.6 millimeters)), the gel can be stripped away from the surface, thus removing contamination from the surface and producing a solid (dry) waste form that can be easily packaged for disposal.

As a system that consists of very simple components and supplies, the ED system is inherently easy to setup, operate and cleanup in most working environments. Its overall portability and ease of use also make it relatively simple to adapt for use in remote applications.

SECTION 3
PERFORMANCE

Demonstration Plan

The purpose of demonstrating the ED system in the RMTF at the INEEL was to validate the ability to use the system with remote tooling like that used at the WVDP (i.e., a PaR 3000 and a CRL Model F MSM). Test methods were designed specifically to simulate in-cell decontamination using ED system instrumentation and components supplied by ADA Technologies, cleaning tools prepared by INEEL Environmental Research and Development Laboratory (ERDL) personnel, and manipulators prepared by RMTF personnel. Demonstration testing was performed on a vertical surface in the mock-up cell shown in Figure 3.1. Testing was done using both an MSM and PaR to apply and remove the electrolyte gel following the two basic test methods. The first method involved testing removal capabilities using surface markings to duplicate the basic properties of fixed contamination (i.e., contamination that cannot be removed by rinsing it with water or by lightly rubbing it away). The second method involved using SIMCON coupons similar to those used during previous tests conducted at the INEEL.

Figure 3.1 RMTF Mock-up Cell

Tests were structured to evaluate system performance according to the categories listed in Table 3.1 - System Testing and Evaluation Summary using each test method.

Table 3.1 - System Testing and Evaluation Summary	
Test Category	**Evaluation Method**
Efficiency	Visual observation of the surface markings. Analysis for SIMCON coupons.
Ease of Use	Total time needed to complete the equipment set-up, gel application and removal, and equipment disassembly and level of difficulty experienced during these operations.
Worker Involvement	Number of workers needed to operate the system.
Waste Generation	Measurement and tracking of the amount of gel used and removed, and the amount of cleanup waste generated during system operation.
Application/ Removal	Time needed to apply and remove gel as measured using a standard stopwatch.
Radiation Tolerance	Examination of a gel sample exposed to a 300 Rad/hr test source for 30 hours to determine durability.
Deployment Estimate	Total time needed to clean 2,000 ft^2 of surface area using the ED system, including equipment set up and disassembly/cleanup operations.

Tests used an ED system specifically configured for remote operation. This configuration included a stainless steel scrubbing shoe that can be held in an MSM grip, a special fixture plate that makes it easier to fit the scrubbing shoe with Scotchbrite® pads used to apply the electrolyte gel, an air pressure manifold that improves gel delivery to the scrubbing shoe, and a foot switch that makes it possible to use the system while operating a manipulator.

To evaluate the system performance according to test parameters using the first test method, system set-up was performed by plugging in the pressurized air source, connecting the product tubing to the cell tubing, making all electrical connections, and plugging the cart-mounted system into a standard 110 V power source. After these preparations were made, process demonstrations began by applying the electrolyte gel to ink markings on the 4-ft^2 test area of the mock-up cell wall. Both a PaR and MSM were used by an operator to demonstrate the gel application process. Following gel application, the system's low voltage current was turned on to initiate electrochemical cleaning of the metal surface. Once this phase of system operation was completed, the electrolyte gel was allowed to dry for a 24-hr period during which time system cleaning was conducted. Gel removal was carried out by fitting the PaR and MSM with a variety of tools and using them to strip off the dried coating. After this phase of testing was completed, the test surface was visually inspected to estimate removal efficiency. Samples of the dried gel also were examined, compacted, and measured to determine how much solid waste was generated during testing.

Initially, test plans had been structured to evaluate ED system performance by removing material chemically bonded, or fixed to a metal surface, and by removing chemical contaminates like those encountered in a radiologically contaminated hot cell (i.e., SIMCON coupons). In order to simulate gel application on a metal surface using the coupons, it was necessary to attach them to the metal surface of the test wall with an electrical ground. Although the coupons available for use during testing had electrical grounds, they were different from those used during previous testing. This introduced inconsistency into the test process, leading to the decision to suspend this phase of the testing and evaluation process.

Previous testing of the ADA ED technology gave excellent results using standard SIMCON coupons.[1] During these tests, an average of 92% of the cesium and 89% of the zirconium were removed. A typical chemical decontamination would remove 80% of the cesium and 20% of the zirconium. A comparison of the ED SIMCON results from previous tests and some other common chemical methods[10] are shown in Table 3.2.

Table 3.2 - Comparison of ED Technology to Chemical Technologies.

Method	Cs, SIMCON Percent Removed	Zr, SIMCON Percent Removed
ED system	92	89
Alkaline chemical decon	82	17
Acid chemical decon	78	23
Multi-step modern chemistry	94	83

Earlier testing with radioactively contaminated stainless steel plates performed in 2002 also gave moderate to high decontamination results.[2] Table 3.3 lists the results of radioactivity survey on the sample surface of both criticality barriers before and after decontamination. It shows that more than 80% of the initial gross radioactive contaminant was removed. The test was repeated on the previously decontaminated surface of the first test article, and it reduced the surface radioactivity further from 8000 dpm/100 cm^2 to approximately 4000 dpm/100 cm^2. This suggests some contaminants in this section of the plate were strongly fixed to the test article. The contamination distribution profile on the original criticality barrier was not known, but the major contaminants were determined to be ^{60}Co and ^{152}Eu, based on swipe sample analyses.

In that study, testing was also performed with two other methods of decontamination[2]. The ED method removed 84% of the contamination on Test Article 1 and 87% on Test Article 2, while wiping the same type of test articles with Windex removed only 19%, and the TLC stripcoat removed 55%.

Table 3.3 - Decontamination of stainless steel plates using ED method.

Radioactivity Measurements		Test Article 1	Test Article 2
Pretest			
Direct Scan	Geiger Counter (bg,dpm/100 cm^2)*	50,000	45,000
	Surface Dosage (mR)	1.5	1.0
Swipe Sample (dpm/100 cm^2)	bg**	13,900, 11,100	18,200, 11,500
	a**	230, 160	310, 200
After 1st Decontamination			
Direct Scan	Geiger Counter (bg, dpm/100 cm^2)*	8,000	6,000
	Surface Dosage (mR)	<0.1	<0.1
Swipe Sample (dpm/100 cm^2)	bg	<1,000	<1,000
	a	<20	<20
% Removal	bg (dpm/100 cm^2, direct scan)	84	87
After 2nd Decontamination			
Direct Scan	Geiger Counter (bg, dpm/100 cm^2)*	4,000	NA
	Surface Dosage (mR)	<0.1	NA
Total % Removal	bg (dpm/100 cm^2, direct scan)	Q	NA

* Peak reading of the test article surface, fume hood floor has background of 3000 dpm/100 cm^2.
** Samples from different locations of test article.

Results

Based on assessment of removal efficiency using the first test method, and evaluation of each test category established for testing, the ED system was found to be an effective removal method that is very easy to set-up, operate, and clean. Visual inspection of the test wall surface after removal of the dried gel showed that at least 80% of the ink markings made on the 4-ft^2 test area had been removed. Additional inspection of gel strips before compaction and measurement showed that manufacturing identification markings on the stainless steel test wall also had been removed by the gel.

Figure 3.2 Removal of ink markings

The ED system showed that connections between internal and external cell areas are simple to make, especially if "quick connect" ports like those available outside of most hot cells are used. Modifications to the scrubbing shoe and other system components made it possible for one operator to apply electrolyte gel to the test surface using either a PaR or MSM. The total amount of solid waste generated by using the strippable coating was found to be consistent with the pre-test estimate of about 0.0005 cubic feet of waste per square foot of surface area cleaned. Although rates of gel application using the MSM and PaR were lower than those possible using a hand-held scrubbing shoe, better rates can be easily achieved by operators as they gain experience in using a manipulator to make gel applications. Removal proved to be more difficult than the application process and required use of a number of different tools before acceptable results could be achieved. After the testing process was completed, it was determined that the gel formula used during the test lacked an ingredient normally included in the formula that makes it easy to detach gel from a surface once it has dried. Additionally, it was determined that the range of tools made available for testing limited the ability to perform efficient removal operations using a manipulator. Both of these factors can be addressed by confirming the formula and demonstrating the process using a different range of tools.

Exposure to the radiation test source for 30 hours in a 300 R/hr field, totaling 9000 Rad exposure, showed that dried gel material remains stable after prolonged exposure. It was estimated that the dried gel sample examined lost less than 10% of its pliability and elasticity through exposure to the test source. Evaluation of system deployment using 2,000 ft^2 as the basis for preparing the estimate showed that an ED system can be deployed within a 72-hr period, including time for system set-up, application and removal, and system disassembly.

SECTION 4
TECHNOLOGY APPLICABILITY AND ALTERNATIVES

Competing Technologies

Steam cleaning, scabbling or chemical cleaning are methods that can be used to accomplish the removal of contamination from metal surfaces like those found in hot cells (i.e., walls, ceilings and equipment surfaces). A summary that shows how using these methods compares with using the ED system is shown in Table 4.1 Decontamination Method Summary Comparison.

Table 4.1 - Decontamination Method Summary Comparison

	Steam Vacuuming	**Scabbling (En-vac Robotic)**	**Chemical Cleaning**	**ED System**
Personnel	3 crew members Rad-tech coverage - full time	3 crew members Rad-tech coverage - full time	2 crew members Rad-tech coverage - intermittent	2 crew members Rad-tech coverage intermittent
Equipment	Robotic vacuum head Steam wands Control unit Water heater Vacuum Demister Cyclone HEPA filter unit	Vacuum - Pentek Scabbling head - Rototeen - Needle Gun	Chemical tankage Sprayers Treatment equip. Grouting equip.	Instrumentation - controls/pump Scrubbing shoe - fixtures & supplies
Training	Radiation Chemicals - hazardous	Radiation Equipment - high power - high pressure	Radiation Chemicals - RCRA Waste - treatment - packaging	Radiation Chemicals - non-hazardous Equipment - manipulators
Preparation	24-hr transport to - work site 5-hr set up	24-hr transport - work site 3-hr set up	Facility dependent 4-hr set up	2-hr transport - work site 4-hr set up
Production	145.2-ft^2/hr	100-ft^2/hr	833-ft^2/hr	48-ft^2/hr
Work Area - typical	Walls Floors Complex parts	Large flat surfaces Walls Floors	Walls Floors Complex parts	Flat surfaces Walls Floors
Access	Large open area Doorway Hatch	Large open area Doorway Hatch	None (equipment within)	Small penetrations

Table 4.1 - Decontamination Method Summary Comparison

	Steam Vacuuming	Scabbling (En-vac Robotic)	Chemical Cleaning	ED System
Equipment - footprint	64-ft^2	120-ft^2	100-ft^2 - tankage - waste treatment	8-ft^2
Hazards	Heat Steam High voltage	High pressure water High voltages	Chemicals - RCRA - corrosive	Chemicals - irritants
Portability	Fairly portable - small units - no heavy equipment	Low - heavy equipment - anchoring needed	Low - tankage - pipes	High - less than 50-lbs
Utilities	110 V/20 amp 480 V/100 amp/3ph	440V/120Va/3ph - compressed air 100 psi 640 scfm	Equipment - chemical handling	110V/20 amp
Cost	$194K	$390K	Facility dependent	$10K

Technology Applicability

Major advantages associated with using the ED system to decontaminate surface areas inside hot cells include size and portability, low material and supply costs, low rates of waste generation and ease of waste treatment and disposal. The technology is commercially available.

Patents /Commercialization/Sponsor

The ED system is available from:

ADA Technologies Inc.
8100 Shaffer Parkway
Suite 130
Littleton, CO 80127

Contacts:

Dr. Rod Sidewell @ ADA Technologies Inc.
(303) 792-5615

The technology is appropriate for consideration where conductive metallic substrates are radioactively contaminated to the degree where hands-on decontamination is challenged under ALARA. The technology should receive strong consideration for the decontamination of steel-lined hot cells and in applications where a minimal volume of solid secondary waste is desired. Typically the latter is associated with applications where an operational liquid radioactive treatment infrastructure is unavailable.

SECTION 5
COST

Methodology

Comparing the ED system with baseline decontamination methods is very difficult, because the ED technology is an enabling technology developed to perform a task for which there is no proven baseline technology. Most other decontamination methods, even those listed in this section, are not readily adapted to the hot cell use (particularly wall cleaning) that the ED system was modified to perform. Table 5.2 gives a comparison of several accepted methods of remote decontamination. Comparing different decontamination methods is always a problem especially if that comparison is a paper study using data collected under different conditions. The advantages and limitations of one method are seldom directly comparable to other methods so the comparison is subject to interpretation

The different methods are the Steam Vacuum Cleaning Technology, the En-vac Robotic Wall Scabbler, and a common chemical wall flushing method. The steam technology evaluation information is taken from the report of a comparison of this method given in a DOE report on its performance.[8] This would be a comparable method to the ED system because of its usefulness on a variety of surfaces, including stainless steel, and its ability to be directed remotely. However, the system tested by DOE in the given report is a hand-held system whose performance (speed, versatility, etc.) is not directly comparable to the remote ED system. This is true to a lesser degree with the En-vac Robotic Wall Scabbler. The En-vac system is truly a robotic unit, with operator controls well removed from the contaminated workpiece. However, during the evaluation test[9] of the En-vac system, much of the work was performed in such a manner that contact manipulation was practical (a significant amount of contact set-up was required for this heavy, bulky equipment). A further difference with the En-vac system and the ED system is that the En-vac was designed for use on concrete and may not work well on stainless steel surfaces. About the closest method for comparison to the ED system is chemical decontamination. Most hot-cells were designed for chemical decontamination, so the systems for chemical application are readily available. One requirement for chemical decontamination that does not readily apply to the WVDP is that a chemical waste system (probably including proper cell containment) is not available. This does not preclude the use of a chemical decontamination system, but may enforce certain additional costs for waste treatment and disposal systems.

The operational costs to deploy the ED system is low. For this report we will assume a 20' X 20' cell, with 20' of height, then the total amount of area (walls and floor) to be cleaned is approximately 2000 ft^2. The time required to perform this cleaning (application and removal) would be approximately 42 hours. Assuming a burdened labor rate of $60/hour for two workers (only one operator is required during use but manipulator work is best broken up over two workers) would yield $5,000. The cost for gel is slated at $50/quart. A quart of gel gives a coverage of approximately 40 ft^2. To clean 2000 ft^2 would require 50 quarts, so a cost of $2,500. The waste generated would be about 1 ft^3 based on the lightly compacted rate of 0.0005 ft^3/ft^2

Cost Analysis

When all the factors are examined, the ED system compares fairly well to the other methods. There are four main advantages of the ED system reflected in Table 5.2: low number of operators required, low amount of solid waste produced, ease of mobilization and low initial cost of the system. The other decontamination systems typically require more operators for the same job. This is partly due to the complexity of the systems; two operators cannot monitor all the functions (steam pressure, vacuum operation, etc) while using the tools. The ED system is basically under the control of the MSM operator in all functions. Two operators have been estimated for the ED system as one operator could not work full time at the manipulators.

Another obvious advantage, and one related to costs, is the waste type and volume produced by the ED system. For the purposes of this evaluation, any liquid produced by the decontamination method is a disadvantage. With the steam and chemical system, a large volume (600 gallons or more) of solution would require treatment (presumably grouting) and disposal. With a chemical system, the disadvantage is more acute because a hazardous waste may have to be treated (as a mixed waste) and the additional volume of water may be generated to remove the chemicals. Treatment of the waste becomes very expensive and could have equipment and personnel exposure repercussions.

The following conditions were assumed for the purpose of estimating the cost of using the ED system and comparing this cost with the cost of using other decontamination methods.

Cell Size/Surface Area: The dimensions of the hot cell being decontaminated are 20-ft (w) by 20-ft (l) by 20-ft (h), with a total surface area of 2,000 ft^2.

Labor : A burdened labor rate of $60.00 per hour was used to determine the cost of using two workers to perform the work, including time for system set up and disassembly.

Materials: One quart of electrolyte gel at a cost of $50.00 per quart is needed to cover 40-ft^2 of surface area.

Waste Disposal: Before packaging, each square foot of solid waste (cured gel) removed from the surface of the cell is compacted to 0.0005 ft^3 of waste material before packaging.

A typical waste disposal cost is $\$150/ft^3$, therefore the waste disposal cost for the ED system for this example is $150. Comparison of these costs to some commonly available decontamination technologies is made is Table 5.1 below.

Table 5.1 - Decontamination Method Cost Comparison

Method	System	Material	Labor	Waste Disposal	Total
ElectroDecon	$10,000	$2,500	$8,600	$150	$21,250
Steam Vacuum	$194,000	$0*	$3,303	$15,000	$212,303
En-vac Robotic Scabbler	$390,000	$0*	$3,600	$33,000	$426,600
Chemical Decon	$0*	$0*	$288	$16,200	$16,488
* Essentially no significant costs in this area for these methods					

One definite advantage is the portability and mobility of the ED system over the other alternatives. Mobilization of the ED system is the simplest of any alternatives. The ED system fits on a hand truck style cart (with the exception of the work fixture) that requires connection to a 110V outlet and a low pressure supply of air. The other systems have several components that are large and not man-portable. As explained earlier, the ED tools can be easily carried into the cell and connections routed via cell penetrations. The En-vac system would require overhead anchors (which are not typically available and may require cell modification) during its use. Placement and retrieval of this tool would be difficult, as it appears to weigh several hundred pounds and is not man-portable, thus requiring a larger personnel dose to mobilize. A portion of the En-vac accessory equipment weighs over 3 tons, and requires 440V, 3 phase electrical support with a very large compressed air service. Mobilizing and maintaining this equipment requires a significant support crew. The control cables, tethers and vacuum hoses are also large enough to require maintaining an open cell entrance during use.

The steam cleaner likewise requires significant resources and cumbersome hoses. It has a trailer mounted vacuum system and steam generator that has electrical power requirements similar to the En-vac system as well as a 3 gal/minute water requirement. This water would require treatment in the WVDP (dry) cells.

Finally, chemical cleaning, while the easiest to implement from a historical perspective, is very problematic when used in nuclear facilities. Again, suitable cell containment (secondary containment) may not be available and secondary waste treatment is required.

Table 5.2 - Comparison of ED system with "baseline" decontamination methods.

Performance Factor	Baseline Technology Steam Vacuum Cleaning System[8]	Alternative Technology En-vac Robotic Wall Scabbler[9]	Chemical Cleaning[7]	ElectroDecon Strippable Coating
Personnel/equipment	• Personnel: • 3 person crew • Full time RCT Coverage • Equipment: • Robotic vacuum head for floor • Steam wands for walls • Various other equipment, control unit, water heater, vacuum with demister, cyclone, HEPA filter unit (each about 4' X 4')	• Personnel: • 3 person crew • Full time RCT Coverage • Equipment: • One Pentek Vac Pac Model 12A • Rotopeen scabbling head12A • Needle Gun scabbling head	• Personnel: • 2 person crew • Intermittent RCT Coverage • Equipment: • Chemical tankage and spray equipment • Chemical treatment equipment • Waste grouting/ solidification equipment	• Personnel: • 2 person crew • Intermittent RCT Coverage • Equipment: • ED control/pump instrument, scrub shoe, work fixture
System Cost	• $194,000	• $390,000	• Unknown	• $10,000
Training required	Radiation Worker (RADWORKER), Hazardous communications (HAZCOM) concerning equipment and hazards, Training typical of large equipment with high power requirements and very hot surfaces.	RADWORKER , HAZCOM, Training typical of large equipment with high power requirements and high pressures.	RADWORKER , HAZCOM, Training typical of hazardous (RCRA) chemicals and waste systems, training in waste treatment and packaging	RADWORKER , HAZCOM, Training typical of non-hazardous chemicals

Table 5.2 - Comparison of ED system with "baseline" decontamination methods.

Performance Factor	Baseline Technology Steam Vacuum Cleaning System[8]	Alternative Technology En-vac Robotic Wall Scabbler[9]	Chemical Cleaning[7]	ElectroDecon Strippable Coating
Preparation time	• 24 hours to transport equipment to work site • 5 hours to setup equipment	• 24 hours to transport equipment to work site • 3 hours to setup equipment	• Unknown, may require only a few hours. • 4 hours to setup equipment	• 2 hours to transport equipment within work site • 4 hours to setup equipment
Production Rate	• 145.2 ft^2/hour	• 100 ft^2/hour	• 833 ft^2/hour	• 48 ft^2/hour
Typical work area locations	• Very versatile, walls, floors, complex parts	• Large flat areas, walls, floors	• Very versatile, walls, floors, complex parts	• Flat surfaces (small and large), walls, floors
Access required to cell	• Large open area and a hatch or doorway	• Large open area and a hatch or doorway	• Probably none, typical cell access is adequate	• Small cell penetration for instrument line and gel hose.
Footprint of equipment	• Estimated 64 ft^2	• Estimated 120 ft^2	• Estimated 100 ft^2 for tanks and waste equipment	• 8 ft^2
Work area hazards	• Heat, steam. High voltages	• High pressure water, high voltages	• Chemical hazards	• Chemical hazards
Waste type and volume	• Water, 0.05 ft^3/ ft^2	• Solid abrasive grit, filters, 0.11 ft^3/ft^2	• Hazardous chemical solution, 0.027 ft^3/ ft^2	• Non-Hazardous solid, 0.0005 ft^3/ft^2
Portability	• Fairly portable (small size units and not too heavy)	• Not very portable (Very heavy, large size, cell mounting anchors required for wall unit)	• Not very portable (cell deluge systems are typically in cell, other tanks, pumps and equipment may be used)	• Very portable (equipment weighs < 50 lbs each, typical cell penetrations may be used for hose and cables)
Utilities/Energy Requirements	• 110V, 20A • 480V, 100A, 3ph	• 440 V, 120kVa, 3ph • 100 psi, 640 scfm compressed air	• Chemical handling equipment	• 110V, 15A

Cost Conclusions

The unit cost for operating the ED process, or any decontamination technology is constructed from subjective judgement related to application specific factors of degree of contamination, surface area to be decontaminated, local waste disposal costs and labor costs. In all these fields the cost issues favor the ED system. As presented in previous sections of this report the cost of procuring the En-vac and steam system (with suitable modifications (estimate $6,000) for in-cell work) exceeds that of the ED system by an order of magnitude. The cost/production rate of the system would favor the other systems over time. However, for hot cell decontamination, this is not the case since none of the production rates of the other systems were purely based on remote work (both demonstrations had significant hands-on work), the true remote production rate is probably closer to the ED systems. The real drawback of the ED system is the removal rate, which with some development and familiarity of use, could compete with the more developed commercial systems.

For reference and determining the lifecycle cost for deploying the ED system a unit cost factor of $\$10.62/ft^2$ can be used, this value is derived from the data provided in Tables 5.1 and 5.2, and Appendix C.

SECTION 6
OCCUPATIONAL SAFETY AND HEALTH

Required Safety and Health Measures

Two safety factors need to be considered before preparing the ED system for use in decontaminating surfaces inside hot cells; potential worker exposure to irritants and basic electrical safety.

Although the gel material used as the electrolyte through which low voltage current is passed is a low hazard material, it can give off some iodine fumes during use. Conducting a thorough review of Material Safety Data Sheets (MSDS) for the proprietary gel is recommended before system deployment begins. Material handling should be performed with latex gloves, safety glasses and other approved protective equipment assigned by an industrial hygienist to ensure against the potential for exposure to any irritating substance during use.

During equipment operations, a worker may be exposed to the electrodes used as part of the ED system. Similar to a battery charger, the current delivered by these 12V/20 amp electrodes is very low, and has not been observed to damage the human body. However, as a preventative measure, electrical safety precautions for using 110V systems should be observed when using the ED system.

Safety and Health Lessons Learned from Demonstrations

Ensure adequate ventilation exists where strippable gel is prepared for application. In the event adequate ventilation may not be achieved using engineering controls, users should consider wearing respirators.

Avoid contact with skin to prevent dermal effects. Users should wear chemical protective gloves and safety glasses to prevent absorption through the skin and eyes.

Implement a comprehensive training program including technology specific training, personal protective equipment (PPE) training, Hazard Communication (HAZCOM) training, and Radiation Worker I & II.

Implement a lockout/tagout program to prevent contact with stored mechanical energy when working on or around the mechanical arm. Additionally, although the device is a plug and cord device not requiring lockout/tagout, users should ensure they are able to control the plug or consider electrical lockout/tagout.

Comparison with Baseline and Alternative Technologies

The ADA Technology was deployed using standard operating procedures for in-cell decontamination work, with due consideration given to the potential electrical hazard and skin irritant issues referenced above.

The ED process is deployed in the same manner as the strippable coating baseline technology, with the only added complexity being the use of the electrochemical deplating component. This has a minimal impact on health and safety and requires the addition of only minor modification to operating procedures to mitigate the slight increase in hazard above that experienced when using strippable coatings alone.

SECTION 7
REGULATORY AND POLICY ISSUES

Regulatory Considerations

No technology specific regulatory permits are required for deployment of the ED process. The process can be used under the requirements of 10 CFR Parts 20 and 835 for protection of workers and the environment from radiological contamination and 29 CFR, OSHA worker requirements.

Risks, Benefits, Environmental and Community Issues

Safety issues associated with the ED process are associated with standard risks of operating remote manipulators in cells and use of portable electrical equipment. Conformance with the data and guidance provided in the MSDS sheets mitigates hazards associated with handling of chemicals when using the gel coating.

The benefits of the process are the ability to employ standard decontamination technology used for application of strippable coatings and expand their decontamination effectiveness to include the ability to solubilize chemically bonded radionuclide contamination and the metallic substrate oxide films associated with them.

There are no community impacts that arise from use of the ED process.

SECTION 8
LESSONS LEARNED

Implementation Considerations

The gel proved to be very difficult to remove after it had dried on the metal surfaces used for testing. There were two probable causes for this. First, each of the three different tools available at the start of testing were not configured specifically for the tests conducted. Second, the gel material used for testing lacked a key ingredient that makes it easier to remove the gel from a metal surface once it has dried.

Developing a scrub shoe that can be used on non-flat surfaces and ceilings will improve system performance.

Electrical isolation of the scrubbing shoe handle can be improved.

APPENDIX A
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APPENDIX B
ACRONYMS AND ABBREVIATIONS

ADA	ADA Technologies
ALARA	As Low As Reasonably Achievable
CFR	Code of the Federal Regulations
D&D	Decontamination and Decommissioning
DOE	U. S. Department of Energy
ED	ElectroDecon
ERDL	Environmental Research and Development Laboratory (at the INEEL)
INEEL	Idaho National Engineering Environmental Laboratory
INTEC	Idaho Nuclear Technology and Engineering Center
LSDDP	Large-Scale Demonstration and Deployment Project
MSDS	Material Safety Data Sheet
MSM	Master-Slave Manipulator
OSHA	Occupational Safety and Health Administration
PPE	Personal Protective Equipment
RCRA	Resource Conservation Recovery Act
RLWR	Radioactive Liquid Waste Reduction
RMTF	Remote Mockup Test Facility
TRA	Test Reactor Area
SIMCON	Simulated Contamination
WVDP	West Valley Demonstration Project

APPENDIX C
COST ESTIMATE FOR ELECTRODECON OPERATION

Basis of Estimated Cost

The activity titles shown in this cost analysis come from observation of the work and the engineers estimate of this type of work in a radioactive hot cell. In the estimate, the activities are grouped under higher-level work titles per the work breakdown structure shown in the Hazardous, Toxic, Radioactive Waste Remedial Action Work Breakdown Structure and Data Dictionary (HTRW RA WBS) (USACE 1996), as reported and compared in the ITSR, En-vac Robotic Wall Scabbler, reference 10. The HTRW RA WBS, developed by an interagency group, is used in this analysis to provide consistency with established national standards.

The costs shown in this analysis are computed from observed duration and hourly rates for the crew and equipment. The following assumptions were used in computing the hourly rates:

- The ED system is assumed to be owned by the Government.
- The equipment hourly rates for the Government's ownership are based on general guidance contained in Office of Management and Budget (OMB) Circular No. A-94, *Cost Effectiveness Analysis*, as reported in previous reference.[10]
- The equipment rates for Government ownership are computed by amortizing the purchase price of the equipment ($10,000), plus a procurement cost of 5.2% of the purchase price, and the annual maintenance costs.
- The ElectroDecon System hourly rate assumes a service life of 15 years. An annual usage of 800 hours per year is estimated for the system ($0.90/hr).
- Some of the equipment used during the demonstration are commonly included in the site motor pool, such as trucks, etc. The equipment rates for these types of equipment are based on standard fleet rates for INEEL.
- The electrical and air supply are assumed to be available as normal plant utilities.
- The estimated standard labor rates established by the INEEL are used and include salary, fringe, departmental overhead, material handling markups, and facility service center markups.

- The equipment rates and labor rates do not include the Bechtel BWXT Idaho, LLC (BBWI) general and administrative (G&A) markups. The G&A are omitted from this analysis to facilitate understanding and comparison with costs for the individual site. The G&A rates for each DOE site vary in magnitude and in the way they are applied. Decision-makers seeking site-specific costs can apply their site's rates to this analysis without having to first back out the rates used at the INEEL.

This analysis does not include costs for oversight engineering, quality assurance, administrative costs for the demonstration, or work plan preparation costs.

Activity Descriptions

The scope, computation of production rates, and assumptions (if any) for each work activity are described below.

Mobilization (WBS 331.01)

Transport and Unload: This item assumes transport of the equipment from an equipment storage area and includes unloading from the truck. The duration used in the cost analysis is based on the test engineer's judgment.

Equipment Set Up: This item includes unpacking, assembly, and connecting hoses. The durations are based to some degree on the time observed from the demonstration, but some adjustment has been made to estimate a hot cell activity. The setup for the ED system took only about 2 hours. But in practice, the set up will probably be ½ hour outside of the cell and ½ hr inside of the cell with some loss (1 hr) for cell preparations. This includes connections to utilities.

Pre-Job Briefing: The duration for the pre-job safety meeting is based upon the estimated time for this activity. The labor costs for this activity are based upon an assumed crew of two operators and the job supervisor (one RCT will intermittently monitor this work); all subsequent activities are also based on the assumed crew.

Don Personal Protective Equipment (PPE): This activity includes the labor and material cost for donning the articles of clothing listed in Table C.1. The duration of the donning and the number of donning events are based on the engineer's judgment.

Table C.1 - Cost for PPE (per man/day)

Equipment	Cost Each	Number of Times Used Before Discarded	Cost Each Time Used ($)	No. Used Per Day	Cost Per Day ($)
Rubber over boots (pvc yellow 1/16 in thick)	$12.15	30	$0.41	1	$0.41
Glove liners pr. (cotton	$0.40	1	$0.40	2	$0.80
inner)	$1.20	1	$1.20	2	$2.40
Rubber Gloves pr. (outer)	$6.47	1	$6.47	1	$6.47
Hoods (yellow)	$3.30	1	$3.30	1	$3.30
Coveralls (white Tyvek)	$4.63	1	$4.63	1	$4.63
Coveralls (green scrubs)	$222	50	$4.44	1	$4.44
Respirator (full face) Cartridges	$751	1	$7.51	2	$15.02
TOTAL COST/DAY/PERSON					**$37.47**

D&D Work (WBS 331.17)

Operational Adjustments: This activity includes adjusting the electrodes, cabling, hose and other equipment to begin the project.

Apply Coating: The rate for applying the gel was determined during the demonstration to be 240 ft^2/hr with MSM. This could probably be improved with time and use. The estimate is based on the example of a 20' X 20' hot cell (floor, walls, no ceiling) for about 2000 ft^2.

Remove Coating: The rate for applying the dry coating was determined during the demonstration to be 60 ft^2/hr with MSM. This could probably be improved with time and use. The estimate is based on the example of a 20' X 20' hot cell (floor, walls, no ceiling) for about 2000 ft^2.

Consumables : Consumables for the ED system include the hose, wires to electrodes, ScotchBrite pads and gel.

- The hose costs $1.63/ft, for 30 ft for this example. That gives a total of $48.90.
- The wire used for this example would be $0.36/ft for 60 ft (30' X 2 electrodes). For a total of $21.60.
- The ScotchBrite pads cost $0.50 and are replaced about every 4 hours. The application would take just over 8 hours, so three pads would be required at a cost of $1.50.
- The gel material costs $50/qt and 50 quarts would be required. That gives a total of $2,500.

As such, the total lump sum cost for the ED system consumables is $2,572.00.

Remove, Move, Set Up: This activity is for disconnecting the ED system from the electrical, air, cabling and hose connections. The observed time required was 15 minutes.

Survey Walls: This activity consists of the radiological survey of the wall using a Ludlum model 2A Survey Meter. The activity duration used in the cost analysis is based on the production rate observed during the demonstration.

Demobilization (WBS 331.21)

Decontaminate and Survey Out: This activity includes possible decontamination of the scrubbing tool and fixture plate. As these tools are small and very portable, they should be stored as slightly radioactive and not decontaminated each use. This also includes packaging and surveying the waste (coating, hose and wires).

Return to Storage: This activity includes transporting the equipment back to the storage area and unloading. The activity duration is based on the test engineer's judgment.

Disposal (WBS 331.18)

Transport and Unload: This activity includes loading the waste onto a truck, transporting to the disposal area, and unloading. The activity requires ½ hour to load, ½ hour to transport, and ½ hour to unload for one trip based on previous experience at the INEEL.

Disposal Coating and PPE: The quantity of waste (coating, hose, wire and PPE) for the ED system is estimated to be 1 ft^3. Disposal costs at the INEEL are assumed to be \$150/ft^3 of waste based on historic costs observed at the INEEL for operation of the disposal cell. These costs do not include costs for transportation, packaging the waste, closure of the disposal facility, or long-term maintenance and surveillance.

Cost Estimate Details

The cost estimate details are summarized in Table C.2. The table breaks out each member of the crew, each labor rate, each piece of equipment used, each equipment rate, each activity duration and all production rates so that site specific differences in these items can be identified and a site specific cost estimate may be developed.

Table C.2 - ED System Cost Summary

Work Breakdown Structure	Unit	Unit Cost $/Unit	Quantity	Total Cost	Computation of Unit Cost: Prod Rate	Duration (hr)	Labor Item	$/hr	Equipment Items	$/hr	Other $	Comments
Facility Deactivation, Decommissioning, & Dismantlement							**Total Cost =**					**$ 7,161.16**
Mobilization (WBS 331.01)										Subtotal =		$ 783.56
Transport & Unload	hr	38.00	0.5	$ 19.00		0.50	OP	38.00	ED, PU	13.40	7	
Equipment Set Up	hr	163.30	2	$ 326.60		2.00	2OP, JS, RCT	163.30	ED	0.90	2	
Pre-Job Briefing	hr	82.55	4	$ 330.20		0.50	2OP, JS, RCT	163.30	ED	0.90	0	0.5 hrs for 8 days
Don PPE	hr	94.08	0.25	$ 23.52		0.25	OP. RCT	73.77	ED, SM	1.40	75.29	$37.47/PPE X 2=$74.94
Doff PPE	hr	73.77	0.25	$ 18.44		0.25	OP, RCT	73.77	ED, SM	1.40	0	
D&D Work (WBS 331.17)										Subtotal =		$ 5,853.24
Operational Adjustments	hr	76.50	1	$ 76.50		0.50	2OP	76.00	ED	0.90	0	
Apply Coating	hr	0.32	2000	$ 633.33	240	8.33	2OP	76.00	ED	0.90	8	
Remove Coating	hr	1.27	2000	$ 2,533.33	60	33.33	2OP	76.00	ED	0.90	30	
Consumables	ls	2,572.00	1	$ 2,572.00				0.00			0.12	
Demobilization (WBS 331.21)										Subtotal =		$ 195.57
Don PPE	hr	74.02	0.25	$ 18.51		0.25	OP, RCT	73.77	ED, SM	1.40	75	$37.47/PPE X 2=$74.94
Remove, Move, Set Up	hr	77.00	1	$ 77.00		1.00	2OP	76.00	ED	0.90	1	
Survey Walls	hr	36.27	0.5	$ 18.14		0.50	RCT	35.77	ED, SM	1.40	1	
Doff PPE	hr	74.02	0.25	$ 18.51		0.25	OP, RCT	73.77	ED, SM	1.40	0	
Decon & Survey Out	hr	36.77	1	$ 36.77		1.00	RCT	35.77	ED, SM	1.40	1	
Return ED System to Storag	hr	38.50	0.5	$ 19.25		0.50	OP	38.00	ED	0.90	0	
Disposal (WBS 331.18)										Subtotal =		$ 328.80
Transport & Unload	hr	76.00	2	$ 152.00		2.00	OP	38.00	PU, ED	13.40	27	
Waste Disposal	cf	150.00	1.00	$ 150.00							150	Disposal fee = $150/cf

Labor and Equipment Rates used to Compute Unit Cost

Crew Item	Rate $/hr	Abbrev-iation	Crew Item	Rate $/hr	Abbreviation	Equipment Item	Rate $/hr	Abbrev-iation	Equipment Item	Rate $/hr	Abbrev-iation
Operator	38.00	OP	Driver	34.35	TD	Pickup Truckj	12.50	PU			
Laborer	32.86	LB	Job Supervisor	51.53	JS	ElectoDecon System	0.90	ED			
Radiation Control Tech	35.77	RCT				Survey Meter	0.50	SM			

Notes:

1. Unit cost = (labor + equipment rate) X duration + other costs, or = (labor + equipment rate)/production rate + other costs
2. Abbreviations for units: ls = lump sum; hr = hour; and; ft^3 = cubic feet